Tsunami Modeling

A tsunami is a destructive natural phenomenon, which can cause enormous infrastructure damage and human losses. Its danger is related both to the impossibility of predicting the time, strength, and location of an underwater earthquake leading to a tsunami and to the specifics of people's settlement.

Most people live in coastal areas, which are highly susceptible to destruction from this phenomenon. However, modern achievements in the field of marine modeling enable us to the assessment of the risks, that potential tsunamis carry, using mathematical modeling. Also, marine models can be used in operational forecasts, which allows for predicting the most important characteristics of tsunamis when an underwater earthquake has already occurred.

The operational tsunami forecast system is aimed at early warning and prevention of human losses, as well as minimizing property and critical infrastructure damage. The forecast system is based on the analysis of seismic observations of earthquake epicenter under the ocean floor and the subsequent assimilation of earthquake data into an effective operational model. The pause between the earthquake and the generated tsunami varies on a wide space-time scale (from minutes to days). In most cases, the margin of time makes it possible to predict the occurrence and moment of tsunami arrival, its height, speed, and propagation time.

The tsunami monitoring and early warning system includes 2 components:
1. System for monitoring seismic or other trigger events in real-time;
2. System for tsunami waves forecasting.

The key characteristics of tsunami waves forecasting are the water level, currents, and wave propagation time for different areas, which vary for earthquakes of various strengths and locations.

MicroStep-MIS's system for the above tsunami features forecasting is based on ROMS (Regional Ocean Modeling System) marine model. ROMS is one of the most widely used mathematical models of the ocean for scientific research and solving practical problems. Its advantages are a large collection of options for customizing model parameters for any region of the globe and a wide range of model applications, especially in coastal and shelf zones. ROMS can be included in the tsunami monitoring and early warning system as a hydrodynamic component of this system. ROMS makes it possible to calculate

the energy in a tsunami epicenter, taking into account both the potential energy created by the vertical rise of the seabed and the kinetic energy created by the speed of the horizontal displacement of the continental slope.

The model can be used for various purposes:
• modeling of dynamics and thermodynamics of the ocean;
• modeling of biogeochemical processes;
• simulation of dynamics and thermodynamics of sea ice (ROMS version with built-in sea ice model);
• study of the interaction between the ocean and the atmosphere.

ROMS accurately reproduces plenty of tsunami characteristics using a two-dimensional representation of the water column and some physical simplifications (such as the hydrostatic approximation). While modeling a tsunami, various earthquake scenarios are available for implementation by tuning

parameters. These parameters are related to the location of the occurred earthquake and its magnitude. The calculation of wave parameters is carried out by taking into account the influence of the seabed relief and the phenomena of wave refraction from various obstacles (from the coastline, underwater ridges, and other relief features). The interaction of waves with each other is also considered. The main output model parameters are the sea level height, the speed, time, and direction of the water flow propagation in space, the tsunami arrival time, the wave amplitude, and its change in time and space. The model can be applied to any region of the Earth, including coastal zones, urban areas, or other densely populated regions along the coastline.

The tsunami modeling system provided by MicroStep-MIS is fully compatible with other products of the company: IMS4 Maps is used for data visualization, IMS4 CLDB is used for data storage and processing.
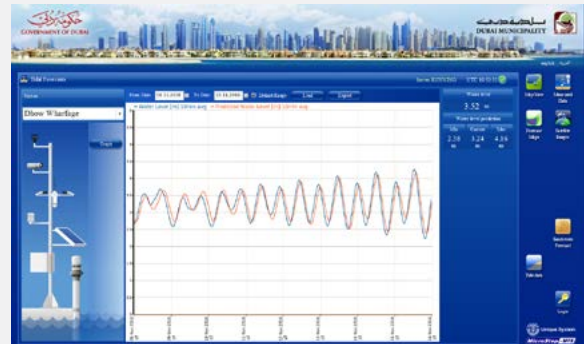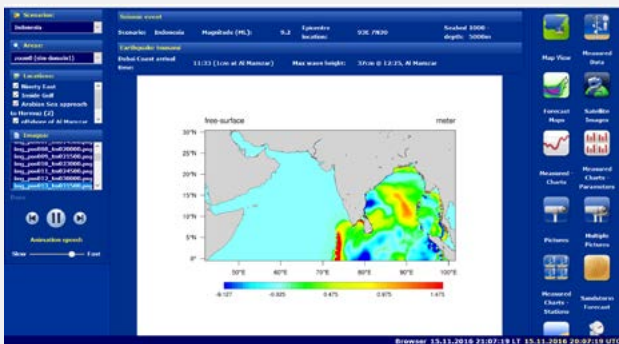
Upper left - IMS4 tsunami forecast application

Upper right and bottom - tsunami forecast system for Dubai Municipality